Predefined Manikins to Support Consideration of Anthropometric Diversity by Product Designers

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Abstract. The paper discusses the complexity involved in considering targeted product users' anthropometric variation in multivariate design problems, such as the design of workplaces or vehicle interiors. The authors argue for the advantages of offering designers a number of predefined digital human models to incorporate in the CAD product models. A study has been carried out in order to illustrate the use of predefined digital human models in vehicle interior design by using the Digital Human Modelling (DHM) tool RAMSIS. The paper takes a designer's view of digital human modelling and illustrates how DHM can be of great value in the design process, but also considers what implications this has on the functionality and usability of DHM tools.

Keywords: Anthropometric Diversity, Digital Human Modelling, Design Process, Product Design, Ergonomics, Human Factors.

1 Introduction

The complexity involved in considering targeted product users' anthropometric variation in multivariate design problems, such as the design of workplaces or vehicle interiors, is not new and was for example described in the 1970s by Roebuck et al. (1975), and more recently by Ziolek and Wawrow (2004) and Robinette and Hudson (2006). The use of digital human modelling (DHM) tools is expected to spread as functionality and value increases, and it is likely that many of the new users will be generalists rather than specialists in anthropometric diversity and its implications for design work. This may have major consequences when attempting to accommodate anthropometric variation amongst the end users of products. Thus, there is a need to make it 'easier to do it correctly', particularly for non-experts, and DHM tools have the potential to assist in meeting this objective. One approach is to offer designers a number of generic predefined digital human models, which might be called a *manikin family*, to incorporate in the CAD product models. Such a family would ideally represent the targeted users well enough, regardless of the design task at hand. The paper aims to illustrate how digital human modelling can be of great value to designers in the design process, but also considers what implications this has on the functionality and usability of DHM tools.

V.G. Duffy (Ed.): Digital Human Modeling, HCII 2007, LNCS 4561, pp. 110–119, 2007.

1.1 Use of Manikin Families in Human Simulation

Starting from the characteristics of the design problem, the DHM tool user typically determines the number of manikins required and their anthropometrical dimensions. This may for example be done by choosing manikins from a set of predefined manikins, each with different anthropometry. However, it is sometimes difficult to determine in advance which manikins are the important ones for a specific design problem, and which manikins could be left out of the analysis. This leaves it to the tool user to carry out the frequently complex selection of appropriate manikins for the design problem at hand. For an expert tool user this might be straightforward, but for a 'common' tool user this is a difficulty and a source of error, especially in multivariate design problems. One approach to this problem is to perform simulations including all members of a manikin family, regardless of whether or not some manikins are important for the specific design task. This approach would be supported by a predetermined set of manikins, e.g. as a company or project standard family of manikins that is established to correctly, or at least adequately, represent the targeted product users. This would be similar to, and indeed a complement to, having a group of real test persons within a company that would always be recruited to assess products being developed. One difference between virtual and real test persons is that the virtual test group will always be available, even concurrently at different places. A concern is that the virtual test group will only do what they are told to do, putting pressure on the tool user to set up the study properly (Ziolek and Kruithof, 2000).

2 Method

A study has been carried out in order to illustrate the use of predefined digital human models in vehicle interior design by using the DHM tool RAMSIS (Seidl, 1997). Of particular interest is how different configurations of families of human models influence the representation of targeted users and hence the accommodation. Two different manikin family configurations were used in the study. The first family is a collection of 17 manikins, specifically modelled in RAMSIS for this study, based on Bittner's A-CADRE family (Bittner, 2000), illustrated in Figure 1.

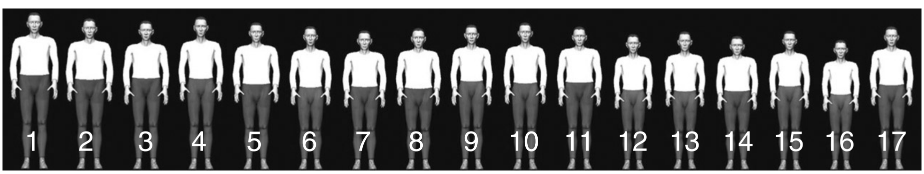

Fig. 1. One of the two manikin families in the study

Starting from a statistical treatment of anthropometric data, Bittner and his colleagues developed the CADRE manikin family, and subsequently developed it into A-CADRE (Bittner et al., 1987; Bittner, 2000). This resulted in anthropometric descriptions for 17 manikins; 16 boundary cases and one centroid case. The A-CADRE family has been validated to capably represent anthropometric diversity, and by using these manikins as user representatives in design, a high level of accommodation can be achieved (Bittner, 2000). Since not all of the 19 body variables in the A-CADRE definition are possible to enter in RAMSIS, the decision was made to just use the three key variables stature, sitting height and waist circumference. Waist circumference is not present in the A-CADRE definition, so values for weight were used instead. This assumption is believed to be adequate due to the relatively high correlation between the two dimensions (Kroemer et al., 2001).

The second family was created by using all manikins in RAMSIS Typology, i.e. a collection of 45 manikins per gender provided as standard in the DHM tool. RAMSIS Typology is based on the theory that the definition of the characterizing property of stature, proportion (ratio of the sitting height and length of the legs) and corpulence of an individual is sufficient to predict all other body dimensions for this person (Flügel et al., 1986; Bubb et al., 2006). The anthropometric database incorporated in RAMSIS was used in the study, with German as the selected nationality, using both genders and 18-70 years as age group. Table 1 show the minimum and maximum percentile value of each key variable for each family approach, for males. The values for female are quite similar, and are available in (Högberg and Case, 2005). The accommodation level that these value ranges answer to was calculated using the multidimensional analysis functionality in two separate anthropometric software packages: PeopleSize 2000 Professional (PeopleSize, 2004) and BodyBuilder (Human-Solutions, 2003).

Table 1 shows that A-CADRE has greater percentile coverage than RAMSIS Typology in stature, but less in sitting height and very similar for waist circumference. Even though different percentile ranges are covered, the two approaches result in approximately the same accommodation level, i.e. approximately 86%. Further reduction in accommodation will happen if more body dimensions limit the design problem (Roebuck et al., 1975). However, this reduction is likely to be

Table 1. Characteristic data of RAMSIS Typology and A-CADRE families

MALE		**RAMSIS Typology**	**A-CADRE**
Stature	min	3%-ile	1%-ile
	max	96.4%-ile	99%-ile
	coverage	93.4%	98%
Sitting height	min	0.9%-ile	3.4%-ile
	max	98.8%-ile	96.6%-ile
	coverage	97.9%	93.2%
Waist circumference	min	4%-ile	3.1%-ile
	max	97.6%-ile	96.9%-ile
	coverage	93.6%	93.8%
Accommodation	PeopleSize	86.8%	87.0%
	BodyBuilder	86%	86%

moderate due to the relatively high correlation of any added dimension with stature, sitting height or waist circumference (which between themselves have low correlation), i.e. the major reduction in accommodation has already been made.

Figure 2 shows skin compositions of all members in the RAMSIS Typology (black) and the A-CADRE (grey) merged into one CAD geometry to illustrate differences in the volume that the two manikin families occupy in standing postures. Their female counterparts are presented in (Högberg and Case, 2005).

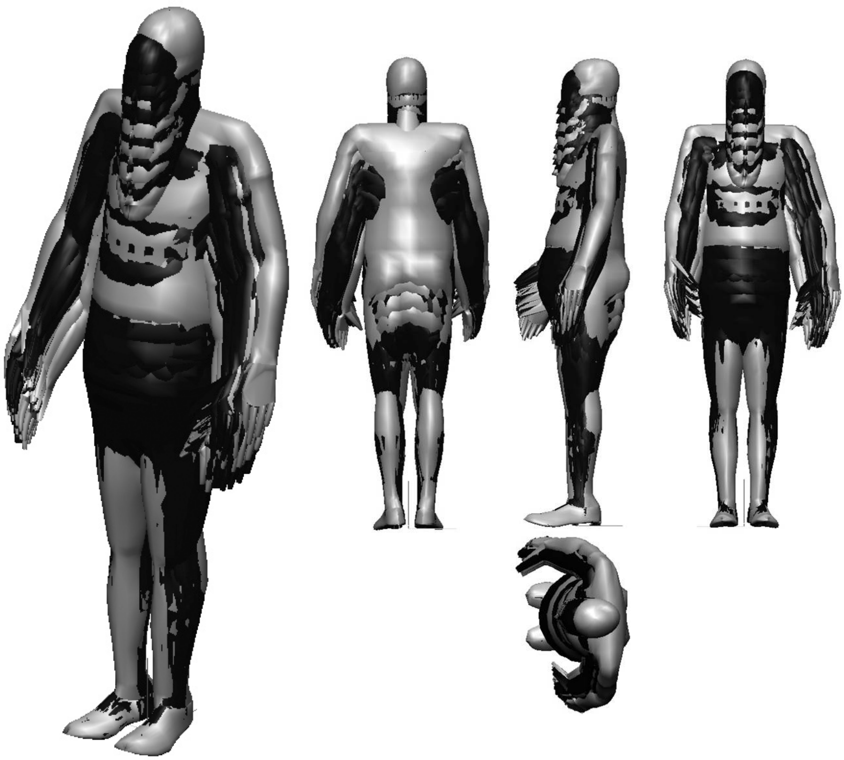

Fig. 2. Skin compositions of RAMSIS Typology (black) and A-CADRE (grey) male manikin families in standing posture

2.1 Context and Details of Study

The study is based on a fixed mid eye study for occupant packaging of the driver in a car. The approach of starting the accommodation task from a fixed eye point is common in aircraft cockpit design (Roebuck et al., 1975) and has been used in some concept cars, e.g. the Volvo Safety Concept Car (VolvoCars, 2004). This is a sensible and likely approach for future cars and requires adjustable pedals/floor, controls, steering wheel and seat.

The constraints are set to keep all manikins' mid eye points (a point right between the eyes) in a fixed position and the line of sight 5 degrees down from the horizontal line. Besides these restrictions, the manikin selects the most comfortable position according to the posture prediction functionality in RAMSIS.

3 Results

Figure 3 show the simulation results for the locations of the steering wheel grasping points, the heel and pedal points as well as the hip points (H-points). These are shown

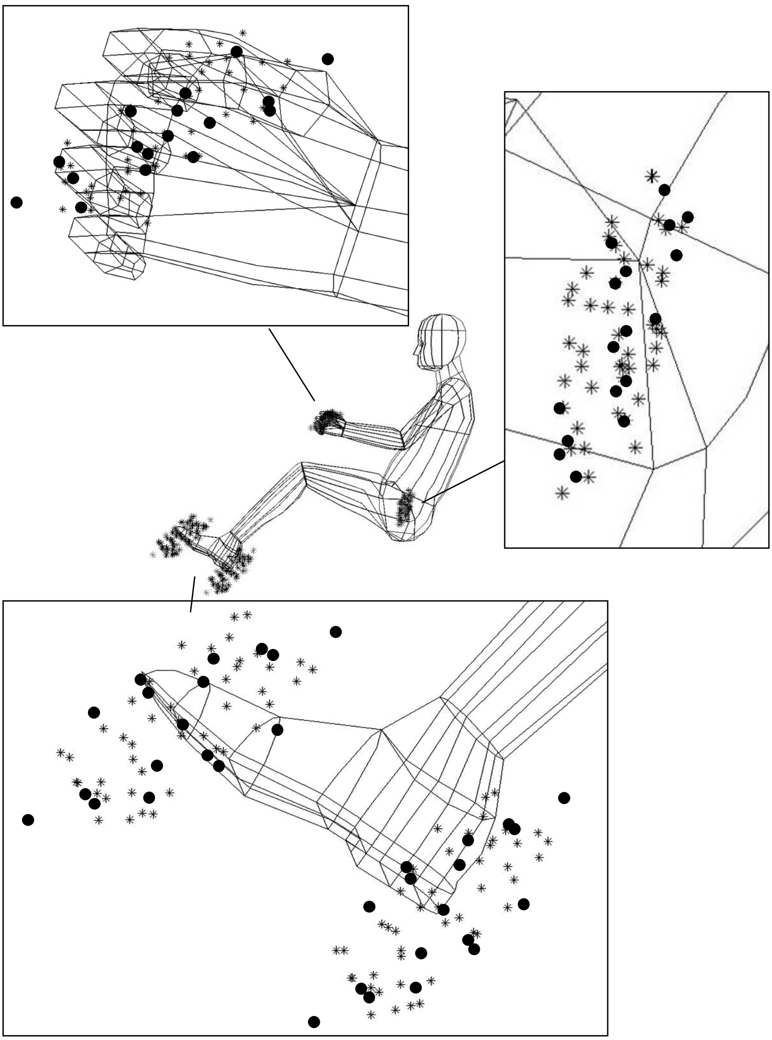

Fig. 3. Body point locations, RAMSIS Typology (Black stars) and A-CADRE (Black dots), males

for each male manikin in both families to enable visual comparison (RAMSIS Typology locations shown as black stars and A-CADRE locations shown as black dots). These points generate interior component adjustment areas required to accommodate drivers in the defined user group (as shown in Figure 4 and 5).

Figure 4 shows adjustment area dimensions generated by using the RAMSIS Typology family, where both genders are included. Figure 5 shows the corresponding results from using the A-CADRE family, both genders. The adjustment area results are compared with a similar fixed eye point study by Vogt et al. (2005) that used a variant of the RAMSIS Typology family. These values are specified in brackets in the figures.

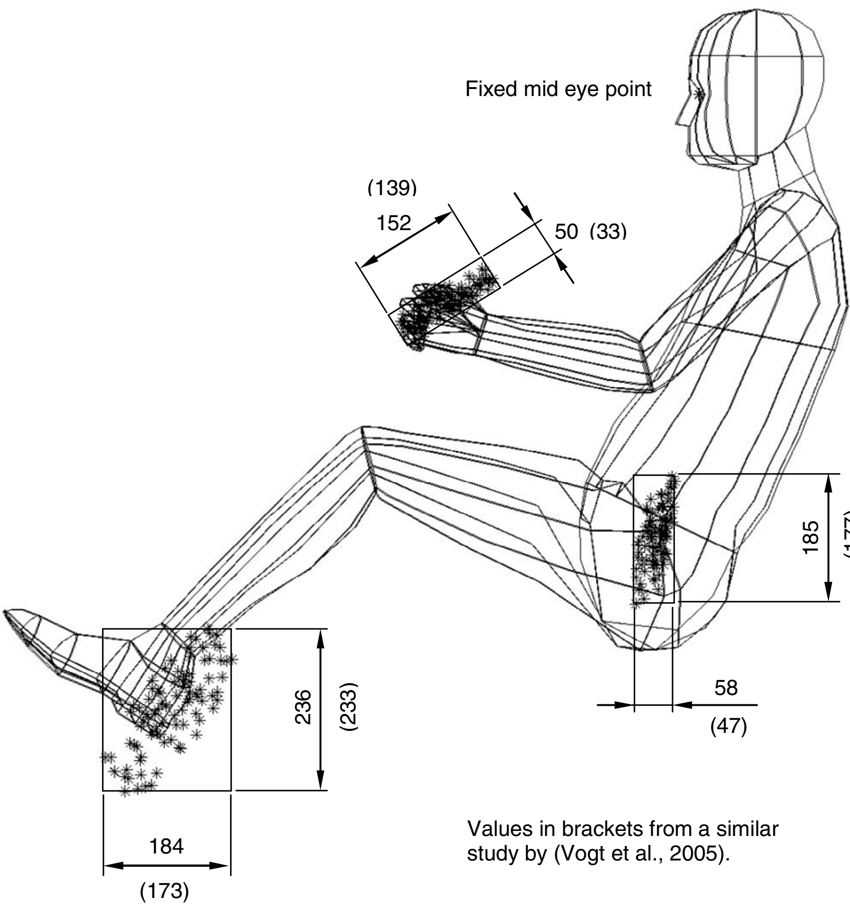

Fig. 4. Adjustment area dimensions obtained, RAMSIS Typology, males and females

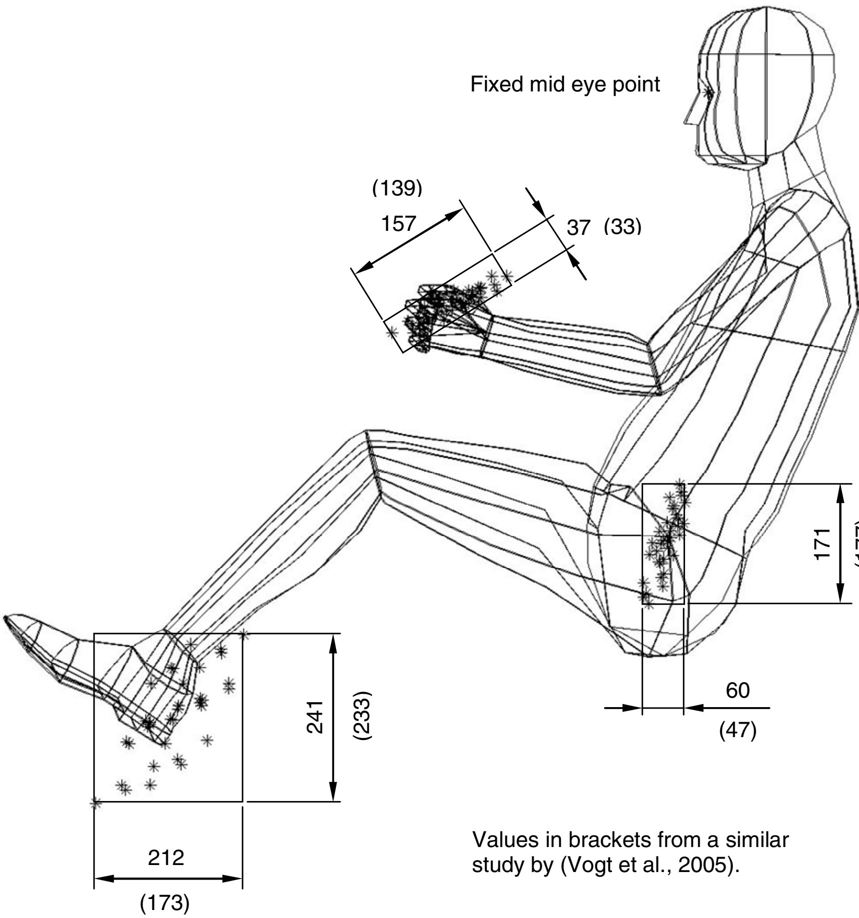

Fig. 5. Adjustment area dimensions obtained, A-CADRE, males and females

4 Discussion

The results indicate that larger adjustments areas are required compared to the study by Vogt et al (2005). This is however expected because of the larger anthropometric coverage in the RAMSIS Typology and the A-CADRE based families which were used (Table 1). For example, the tallest person in Vogt's study is 1897 mm, whereas the tallest persons in RAMSIS Typology and A-CADRE families were 1909 mm and 1947 mm respectively. The RAMSIS Typology seems to represent corpulence differently than A-CADRE. Table 1 shows similar coverage of corpulence but Figure 2 indicates that the RAMSIS Typology represents corpulence to a higher degree (hence the black abdomen), particularly for shorter persons. This may be an effect of sources of anthropometric data when creating the manikin families, and particularly of correlations between body measurements. The RAMSIS Typology is mainly based on large anthropometric surveys done in Germany by measuring civilians (Flügel et al., 1986; Human-Solutions, 2004), whereas the A-CADRE is mainly based on US Army personnel data (Bittner, 2000). It is likely that people represented in the US study are on average fitter than people in the German study, and hence that the RAMSIS Typology manikin family more accurately represents corpulence of common people. Both manikin family approaches embody human diversity in a credible way. Even though it is hard to draw major conclusions from this study, it is worth emphasising that A-CADRE gave these results by 62% fewer simulations required (34 compared to 90). A boundary cases selection approach is appropriate for the kind of design problem presented in this paper (Dainoff et al., 2003). For other types of design tasks a distributed cases method is more appropriate, e.g. for clothing design (Dainoff et al., 2003). In this sense the RAMSIS Typology approach is more general since it includes cases (manikin descriptions) within a distribution as well as on the boundary, whereas in A-CADRE all manikin description are on the boundary, except the centroid case.

From a general perspective the study is used as an illustration of DHM tools becoming everyday tools for designer. Supporting designers with a DHM tool that has appropriate functionality and usability makes the complexity involved in considering anthropometric variation in multivariate design problems less demanding. Enabling the human simulation tool user to see and operate the product user as well as the product modelled in the same virtual environment means that human-product interaction issues are more easily considered concurrently with other design issues, thereby supporting the synthesis work that is characteristic of design. The implementation of pre-defined manikin families in human simulation tool aids the tool user to consider anthropometric diversity rather straightforwardly even though not being required to know the problems in detail or the theory behind the manikin family, but rather putting effort into making sure that all manikins are accommodated by the design. Several sources report on problems and deficiencies in considering ergonomics when designing products and workstations, and how this puts pressure on the usability of the ergonomics information available to designers, e.g. (Haslegrave and Holmes, 1994; Chapanis, 1995; Burns et al., 1997; Rouse and Boff, 1998). DHM tools have the potential to act as a channel for conveying ergonomics information to designers, e.g. to support understanding and interest during the explorative, generative and evaluative activities of the design process. Careful evaluation of proposed solutions is important in order to identify and assess feasible solutions that balance all applicable requirements in a good way. Evaluation can be considered as being performed in the 'small' or 'big'. Evaluation in the 'small' is meant to convey the almost continuous evaluation of generated ideas that are performed by the designer, or the design team, as portrayed by the evaluation segment (Ev) of the 'wheel' in Figure 6. The figure is inspired by design process representations in (Pahl and Beitz, 1988) and (Cross, 2000). An evaluation in the 'big' would represent evaluations carried out more rarely, but possibly more thoroughly, and likely to also involve people other than the design engineers, e.g. specialists and managers. Typically such evaluations are done when progressing from one design process stage to the next, e.g. from conceptual design to embodiment design (Figure 6). However, although these 'big' evaluations may discover deficiencies of some sort, time and cost pressures frequently hinder the alteration of the design in any major way. This means that the required design iteration is rejected, but regularly the design process continues. Hence, there may be great process advantages of supporting designers with appropriate DHM tool functionality when performing evaluations in the 'small'. These are alleged to be particularly valuable within active conceptual design process phases, where important choices and iterations are made for finding the best overall balance of the array of product requirements. However, this puts demands on the usability of the tools, particularly for non-specialist users, who also may use the tools infrequently. In addition, there is a need for a structured process when using DHM tools, and a need for integrating the tools in the general product development processes of companies (Hanson et al., 2006).

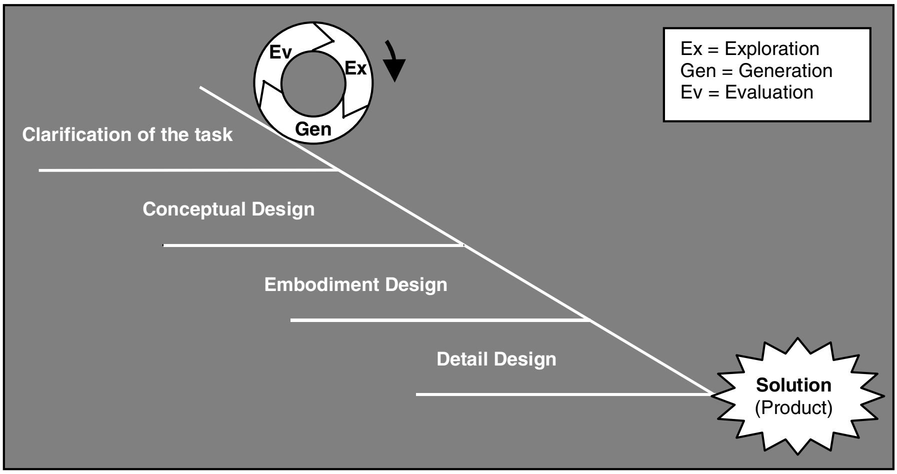

Fig. 6. Design process representation for illustrating evaluation in the 'small' and the 'big'

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